
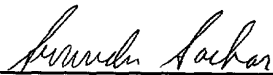


FORM PTO-1390 (Modified) (REV 11-2000)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER 220800US2XPCT
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371			U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 10/089156)
INTERNATIONAL APPLICATION NO. PCT/JP00/05153	INTERNATIONAL FILING DATE 31 July 2000	PRIORITY DATE CLAIMED None	
TITLE OF INVENTION WAVELENGTH DIVISION MULTIPLEXING AND OPTICAL TRANSMISSION APPARATUS			
APPLICANT(S) FOR DO/EO/US Hiroaki MUNEHIRA et al.			
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:			
<ol style="list-style-type: none"> 1. <input checked="" type="checkbox"/> This is a FIRST submission of items concerning a filing under 35 U.S.C. 371. 2. <input type="checkbox"/> This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371. 3. <input checked="" type="checkbox"/> This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below. 4. <input type="checkbox"/> The US has been elected by the expiration of 19 months from the priority date (Article 31). 5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371 (c) (2)) <ol style="list-style-type: none"> a. <input type="checkbox"/> is attached hereto (required only if not communicated by the International Bureau). b. <input checked="" type="checkbox"/> has been communicated by the International Bureau. c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US). 6. <input checked="" type="checkbox"/> An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). <ol style="list-style-type: none"> a. <input checked="" type="checkbox"/> is attached hereto. b. <input type="checkbox"/> has been previously submitted under 35 U.S.C. 154(d)(4). 7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3)) <ol style="list-style-type: none"> a. <input type="checkbox"/> are attached hereto (required only if not communicated by the International Bureau). b. <input type="checkbox"/> have been communicated by the International Bureau. c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired. d. <input checked="" type="checkbox"/> have not been made and will not be made. 8. <input type="checkbox"/> An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)). 10. <input type="checkbox"/> An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)). 11. <input type="checkbox"/> A copy of the International Preliminary Examination Report (PCT/IPEA/409). 12. <input checked="" type="checkbox"/> A copy of the International Search Report (PCT/ISA/210). 			
Items 13 to 20 below concern document(s) or information included:			
<ol style="list-style-type: none"> 13. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 14. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 15. <input type="checkbox"/> A FIRST preliminary amendment. 16. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment. 17. <input type="checkbox"/> A substitute specification. 18. <input type="checkbox"/> A change of power of attorney and/or address letter. 19. <input type="checkbox"/> A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825. 20. <input type="checkbox"/> A second copy of the published international application under 35 U.S.C. 154(d)(4). 21. <input type="checkbox"/> A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4). 22. <input type="checkbox"/> Certificate of Mailing by Express Mail 23. <input checked="" type="checkbox"/> Other items or information: Form PTO-1449/ Drawings (6 sheets) PCT/IB/308/ Cited References (1) Statement of Relevancy 			

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.101) 10/089156		INTERNATIONAL APPLICATION NO. PCT/JP00/05153		ATTORNEY'S DOCKET NUMBER 220800US2XPCT													
24. The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) : <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO \$1040.00 <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO \$890.00 <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO \$740.00 <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) \$710.00 <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) \$100.00 ENTER APPROPRIATE BASIC FEE AMOUNT =				CALCULATIONS PTO USE ONLY													
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).				\$890.00													
<table border="1"><thead><tr><th>CLAIMS</th><th>NUMBER FILED</th><th>NUMBER EXTRA</th><th>RATE</th></tr></thead><tbody><tr><td>Total claims</td><td>6 - 20 =</td><td>0</td><td>x \$18.00</td></tr><tr><td>Independent claims</td><td>1 - 3 =</td><td>0</td><td>x \$84.00</td></tr></tbody></table>				CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	Total claims	6 - 20 =	0	x \$18.00	Independent claims	1 - 3 =	0	x \$84.00	\$0.00	
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a. <input checked="" type="checkbox"/> A check in the amount of \$890.00 to cover the above fees is enclosed.																	
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NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.																	
SEND ALL CORRESPONDENCE TO:																	
 22850 Surinder Sachar Registration No. 34,423			 SIGNATURE Marvin J. Spivak NAME 24,913 REGISTRATION NUMBER March 27 2002 DATE														

SPECIFICATION

TITLE OF THE INVENTION

WAVELENGTH DIVISION MULTIPLEXING AND OPTICAL TRANSMISSION APPARATUS

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TECHNICAL FIELD

The present invention relates to a wavelength division multiplexing and optical transmission apparatus in which transmission quality is heightened in a stage of a small number of initial setting wavelengths by installing a non-input optical amplifier to produce a dummy of an optical signal additionally set in the future.

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BACKGROUND ART

A submarine optical cable transmission method is classified into a non-relay method applied for a strait crossing and a long distance relay method including a submarine relay device with which an ocean crossing is intended. A submarine optical cable relay transmission system requiring of the long distance relay method is composed of a submarine relay transmission line and coast station devices of land placed on both ends of the submarine relay transmission line, and a plurality of submarine relay devices are normally installed at relay span intervals of almost 50 Km in the submarine optical cable relay transmission system. As a technique of efficiently transmitting a plurality of pieces of information through an optical cable, a wavelength division multiplexing and optical transmission technique is known. In this wavelength division multiplexing and optical transmission technique, a plurality of signals are allocated to a plurality of optical signals having wavelengths different from each other in one-to-one correspondence (division), the optical signals are multiplexed to a multiplexed optical signal, and the multiplexed

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optical signal is transmitted in two-way communication by using two optical fibers. On a transmission side, a plurality of optical signals sent from sources of optical signals of wavelengths different from each other are multiplexed to a multiplexed optical signal in an optical
 5 multiplexer. In a reception side, the multiplexed optical signal is demultiplexed to the optical signals having the wavelengths different from each other in an optical demultiplexer, and the optical signals are transformed into a plurality of electric signals in an optical receiving element. In this technique, a merit of making possible to
 10 transmit a large amount of information attracts attention.

Fig. 1 is a block diagram showing the configuration of a conventional wavelength division multiplexing and optical transmission apparatus. In Fig. 1, 1-m to 1+m indicate a plurality of optical transmitting units for modulating a plurality of laser signals having wavelengths
 15 $\lambda - m$ to $\lambda + m$ different from each other with a plurality of data signals respectively and outputting a plurality of modulated optical signals. 2 and 3 indicate dummy optical signal sources. 4 indicates an optical multiplexer. 5 indicates an optical fiber. 6 indicates a conventional wavelength division multiplexing and optical transmission apparatus.
 20 In this example, the conventional wavelength division multiplexing and optical transmission apparatus 6 is installed in a coast station device.

Next, an operation will be described.

A plurality of laser signals having wavelengths $\lambda - m$ to $\lambda + m$ different
 25 from each other are modulated with a plurality of data signals in the optical transmitting units 1-m to 1+m, of which the number is $2m$, in one-to-one correspondence, and a plurality of modulated optical signals are output. In cases where the demand of the number of wavelengths in a telecommunication line is $2m$ (m is normally equal to a value ranging
 30 from 4 to 8) in the early stage in which the conventional wavelength

division multiplexing and optical transmission apparatus 6 is installed, the optical transmitting units 1-m to 1+m are installed. Also, as the demand of the number of wavelengths is increased, a plurality of optical transmitting units are additionally installed until the total number of optical transmitting units reaches a maximum setting wavelength number $2n$ (n is normally equal to a value ranging from 32 to 64). A transmission band width is determined according to a plurality of optical amplifier repeaters connected with each other in multistage and characteristics of an optical fiber. In case of a combination of a plurality of C-band optical amplifier repeaters using a plurality of erbium doped optical fiber amplifiers (EDFA) and a non-zero distributed shift optical fiber, a transmission band width is almost equal to 30 nm. A plurality of divided wavelength bands are obtained by dividing a transmission wavelength band at equal intervals, and each of the optical signals output from the optical transmitting units 1-n to 1+n has a spectral line width in a wavelength band placed within one divided wavelength band. A dummy optical signal of a prescribed wavelength λ_2 and a dummy optical signal of a prescribed wavelength λ_3 are output from the dummy optical signal sources 2 and 3 without modulation. The wavelengths λ_2 and λ_3 are placed on the outside of a wavelength band which is occupied by the optical signals output from the optical transmitting units 1-m to 1+m and correspond to wavelengths of optical signals output from the optical transmitting units 1-n to 1+n additionally installed in the future. As a view of a plurality of spectral lines is shown in Fig. 2, the dummy optical signal of the wavelength λ_2 is adjacent to a modulated optical signal of the wavelength $\lambda-m$ on a shorter wavelength side, and the dummy optical signal of the wavelength λ_3 is adjacent to a modulated optical signal of the wavelength $\lambda+m$ on a longer wavelength side. These dummy optical signals output from the dummy optical signal sources 2 and 3 are multiplexed

in the optical multiplexer 4 with the modulated optical signals output from the optical transmitting units 1-m to 1+m and are transmitted to a submarine relay device or the other coast station device through the optical fiber 5. In this case, the dummy optical signals placed on both sides of a wavelength band of the modulated optical signals function so as to reduce a peak power of each modulated optical signal. In detail, in an optical amplification relay transmission system, a power of each modulated optical signal is almost determined to a value which is obtained by dividing a saturation power of each optical amplifier repeater installed in a proper position of an optical signal transmission line by the number of wavelengths. Assuming that the number of wavelengths is small, a power of each modulated optical signal is excessively heightened so as to cause non-linear optical effects in the transmission line of optical fiber 5. Therefore, a problem has arisen that the transmission quality of the modulated optical signals considerably deteriorates. As non-linear optical effects causing the deterioration of the transmission quality, a four wavelength mixing (FWM) and a self phase modulation (SPM) are well known. The FWM and the SPM are disclosed in detail in "Nonlinear Fiber Optics, Academic Press, 1995, New York" written by G. P. Agrawal. In case of the conventional wavelength division multiplexing and optical transmission apparatus 6 in which the dummy optical signals are placed in adjacent to the wavelength band occupied by the modulated optical signals, the optical amplifier repeater is operated so as to set a sum of powers of the modulated optical signals and the dummy optical signals to a constant value. Therefore, a sum of the powers of the modulated optical signals output from the optical amplifier repeater is suppressed, the adverse influence of the non-linear optical effects in the optical fiber 5 is considerably reduced, and the transmission quality can be maintained.

Also, the dummy optical signals placed on both sides of the wavelength band of the modulated optical signals function so as to apparently widen the wavelength band occupied by the modulated optical signals. In detail, in a submarine optical cable relay transmission system, the optical amplification is repeatedly performed at needs in a plurality of optical amplifier repeaters (not shown) placed on proper positions of the optical transmission line. Each optical amplifier repeater is designed so as to optimize a gain profile of the modulated optical signals in cases where the number of wavelengths of the modulated optical signals input to the optical amplifier repeater is maximized. Therefore, in cases where the number of wavelengths used in the early operation is small, when the optical amplifier repeater is operated for the small number of wavelengths, a gain profile corresponding to the small number of wavelengths differs from that assumed in the designing of the optical amplifier repeater. Therefore, when the optical amplification is repeatedly performed in the optical amplifier repeaters, a gain difference is remarkably increased in the modulated optical signals according to the gain profile set in the designing of each optical amplifier repeater. In a case of the conventional wavelength division multiplexing and optical transmission apparatus 6 in which the dummy optical signals are placed in adjacent to the wavelength band occupied by the modulated optical signals, the optical amplifier repeaters are operated so as to control the sum of the output powers of the modulated optical signals and the dummy optical signals to a constant value. Therefore, the same gain profile as that set in the designing of each optical amplifier repeater is obtained in the optical amplifier repeater, the adverse influence of the gain difference on the modulated optical signals is considerably reduced, and the transmission quality of the modulated optical signals can be maintained.

However, in the conventional wavelength division multiplexing and

optical transmission apparatus 6, because each of the dummy optical signal sources 2 and 3 is formed of a laser diode from which a laser signal of a single wavelength is emitted, a spectral line width of the output laser signal is narrow. Therefore, a stimulated Brillouin scattering (SBS) denoting the non-linear optical effects is caused, and a problem has arisen that the transmission quality of the modulated optical signals deteriorate. Also, because each output laser signal is polarized in an inherent direction, there is a case where the lowering of a gain of each modulated optical signal polarized in a specific direction or a change-with-time of a degree of the lowering of the gain is caused due to the polarization dependent gain (PDG) of the optical amplifier repeater. In this case, it is necessary to use a polarization scrambler (PSCR) so as to prevent the deterioration of an S/N ratio of the modulated optical signal by performing non-polarization for the polarized optical signal. Therefore, a problem has arisen that a size of the wavelength division multiplexing and optical transmission apparatus is enlarged and it is difficult to reduce the cost of the production of the wavelength division multiplexing and optical transmission apparatus. Also, in cases where a technical improvement is planned to widen the wavelength band occupied by the modulated optical signals for the purpose of increasing the number 2m of wavelengths of the modulated optical signals, because each of the dummy optical signal sources 2 and 3 is formed of a laser diode from which a laser signal of a single wavelength is emitted, the dummy optical signal sources 2 and 3 cannot be accommodated to a system change. Therefore, it is required to newly prepare a dummy optical signal source possible to be accommodated to a new system, and a problem has arisen that it becomes more and more difficult to reduce the cost of the production of the wavelength division multiplexing and optical transmission apparatus.

The present invention is provided to solve the above-described problems, and the object of the present invention is to provide a wavelength division multiplexing and optical transmission apparatus in which a plurality of modulated optical signals can be transmitted without degrading transmission quality of the modulated optical signals by using a non-input optical amplifier even though the number of wavelengths of the modulated optical signals used at the early time is small, a gain difference caused in an optical transmission wavelength band is compensated and the transmission quality is heightened.

DISCLOSURE OF THE INVENTION

A wavelength division multiplexing and optical transmission apparatus according to the present invention comprises a plurality of optical transmitting units for modulating a plurality of laser signals having inherent wavelengths with a plurality of data signals and outputting a plurality of modulated optical signals, optical amplifying means for outputting an amplified spontaneous emission light signal (ASE), band pass filtering means for setting an occupied wavelength band of the modulated optical signals output by the optical transmitting units, an additional wavelength band possible to be additionally installed in the future and a neighboring wavelength band of both the occupied wavelength band and the additional wavelength band as a filtering wavelength band and band-filtering the amplified spontaneous emission light signal output by the optical amplifying means and outputting a non-modulated spectrum slice optical signal, and optical multiplexing means for multiplexing the non-modulated spectrum slice optical signal output by the band pass filtering means with the modulated optical signals output by the optical transmitting units and transmitting a multiplexed optical signal.

In the above configuration, the amplified spontaneous emission light

signal is band-filtered to obtain the spectrum slice optical signal, and the spectrum slice optical signal functioning as a dummy optical signal is multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signal or band components of the spectrum slice optical signal can be arbitrarily processed. Also, because a spectrum line width of the spectrum slice optical signal can be widened, there is no probability that a transmission quality of the modulated optical signals is degraded due to the stimulated Brillouin scattering (SBS). Also, because the polarization in an inherent direction does not exist in the modulated optical signals, there is no probability that the reduction of gains of the modulated optical signals or a change-with-time of a degree of the reduction of the gains of the modulated optical signals is caused due to the polarization dependent gain (PDG) of each optical amplifier repeater. Accordingly, the deterioration of an S/N ratio can be prevented. Also, it is not required to prepare a polarization scrambler (PSCR) for the purpose of obtaining the modulated optical signals of no polarization, and it is not required to prepare a new dummy optical signal source in the widening of the optical transmission wavelength band for the purpose of increasing the number of wavelengths of the modulated optical signals. Accordingly, the enlarging of the size of the wavelength division multiplexing and optical transmission apparatus can be suppressed, and the cost of the production of the wavelength division multiplexing and optical transmission apparatus can be reduced.

In the wavelength division multiplexing and optical transmission apparatus according to the present invention, the optical amplifying means comprises a pair of optical amplifiers which each have a signal input terminal terminated at no reflection, and the bandpass filtering means comprises a pair of optical band pass filters for setting both

the occupied wavelength band of the modulated optical signals output by the optical transmitting units and the neighboring wavelength band of the occupied wavelength band as the filtering wavelength band, filtering the amplified spontaneous emission light signal output by the optical amplifiers and outputting a pair of non-modulated spectrum slice optical signals.

In the above configuration, a plurality of spontaneous emitted laser signals are output by using the optical amplifiers which each have a signal input terminal terminated at no reflection, the spontaneous emitted laser signals are band-filtered in the optical bandpass filters respectively to obtain spectrum slice optical signals, and the spectrum slice optical signals functioning as dummy optical signals are multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signals or band components of the spectrum slice optical signals can be arbitrarily processed. Also, because a spectrum line width of each spectrum slice optical signal can be widened, there is no probability that a transmission quality of the modulated optical signals is degraded due to the stimulated Brillouin scattering (SBS). Also, because the polarization in an inherent direction do not exist in the modulated optical signals, there is no probability that the reduction of gains of the modulated optical signals or a change-with-time of a degree of the reduction of the gains of the modulated optical signals is caused due to the polarization dependent gain (PDG) of each optical amplifier repeater. Accordingly, the deterioration of an S/N ratio can be prevented. Also, it is not required to prepare a polarization scrambler (PSCR) for the purpose of obtaining the modulated optical signals of no polarization, and it is not required to prepare a new dummy optical signal source in the widening of the optical transmission wavelength band of the optical amplifier repeater for the purpose of increasing the number

of wavelengths of the modulated optical signals. Accordingly, the enlarging of the size of the wavelength division multiplexing and optical transmission apparatus can be suppressed, and the cost of the production of the wavelength division multiplexing and optical transmission apparatus can be reduced. Also, in cases where a technical improvement is performed to widen the occupied wavelength band of the modulated optical signals for the purpose of increasing the number of wavelengths of the modulated optical signals, the technical improvement can be performed by only changing the optical band pass filters connected to the optical amplifiers to those having required band pass filtering characteristics. Therefore, it is not required to newly prepare a dummy optical signal source possible to be accommodated to a new system, and the new system of the wavelength division multiplexing and optical transmission apparatus can be obtained without increasing the cost.

In the wavelength division multiplexing and optical transmission apparatus according to the present invention, the optical amplifying means comprises a single optical amplifier which has a signal input terminal terminated at no reflection, and the bandpass filtering means comprises a light dividing element for dividing the amplified spontaneous emission light signal output by the optical amplifier into a plurality of amplified spontaneous emission light signals, and a plurality of optical band pass filters, connected to a plurality of divided output terminals of the light dividing element respectively, for outputting the non-modulated spectrum slice optical signal.

In the above configuration, an amplified spontaneous emission light signal is output by using the single optical amplifier which has a signal input terminal terminated at no reflection, the amplified spontaneous emission light signal is divided into a plurality of amplified spontaneous emission light signals, the amplified

spontaneous emission light signals are band-filtered in the optical band pass filters respectively to obtain a plurality of spectrum slice optical signals, and the spectrum slice optical signals functioning as a plurality of dummy optical signals are multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signals or band components of the spectrum slice optical signals can be arbitrarily processed by using the band pass filtering means of a minimum size which is obtained by combining the single optical amplifier and the plurality of optical band pass filters. Also, because a spectrum line width of each spectrum slice optical signal can be widened, there is no probability that a transmission quality of the modulated optical signals is degraded due to the stimulated Brillouin scattering (SBS). Also, because the polarization in an inherent direction do not exist in the modulated optical signals, there is no probability that the reduction of gains of the modulated optical signals or a change-with-time of a degree of the reduction of the gains of the modulated optical signals is caused due to the polarization dependent gain (PDG) of each optical amplifier repeater. Accordingly, the deterioration of an S/N ratio can be prevented. Also, it is not required to prepare a polarization scrambler (PSCR) for the purpose of obtaining the modulated optical signals of no polarization, and it is not required to prepare a new dummy optical signal source in the widening of the optical transmission wavelength band of the optical amplifier repeater for the purpose of increasing the number of wavelengths of the modulated optical signals. Accordingly, the enlarging of the size of the wavelength division multiplexing and optical transmission apparatus can be suppressed, and the cost of the production of the wavelength division multiplexing and optical transmission apparatus can be reduced. Also, in cases where a technical improvement is performed to widen the occupied wavelength band of the

modulated optical signals for the purpose of increasing the number of wavelengths of the modulated optical signals, the technical improvement can be performed by only changing the optical band pass filters connected to the optical amplifiers to those having required band pass filtering characteristics. Therefore, it is not required to newly prepare a dummy optical signal source possible to be accommodated to a new system, and the new system of the wavelength division multiplexing and optical transmission apparatus can be obtained without increasing the cost.

In the wavelength division multiplexing and optical transmission apparatus according to the present invention, the optical amplifying means comprises a single optical amplifier which has a signal input terminal terminated at no reflection, and the bandpass filtering means comprises a light dividing element for dividing the amplified spontaneous emission light signal output by the optical amplifier into a plurality of amplified spontaneous emission light signals, a plurality of optical band pass filters connected to a plurality of divided output terminals of the light dividing element respectively, an optical multiplexer for multiplexing two or more outputs of the optical band pass filters with each other and outputting the non-modulated spectrum slice optical signal, and an optical amplifier for amplifying an output of the optical multiplexer while controlling a power of the output to a constant value.

In the above configuration, an amplified spontaneous emission light signal is output by using the single optical amplifier which has a signal input terminal terminated at no reflection, the amplified spontaneous emission light signal is divided into a plurality of amplified spontaneous emission light signals, the amplified spontaneous emission light signals are band-filtered in the optical band pass filters respectively to obtain a plurality of spectrum slice

optical signals, the spectrum slice optical signals are amplified for each block, and the spectrum slice optical signals functioning as a plurality of dummy optical signals are multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signals or band components of the spectrum slice optical signals can be arbitrarily processed by using the band pass filtering means which is obtained by combining the single optical amplifier and the plurality of optical band pass filters. Also, even though one of the optical band pass filters is put in an inoperative condition, in the optical amplifier in which an amplified spontaneous emission light signal of a specific wavelength planned to be output from the optical band pass filter put in the inoperative condition is amplified with other amplified spontaneous emission light signals, the other amplified spontaneous emission light signals are amplified at stronger gains, and the emphasized gains of the other amplified spontaneous emission light signals adjacent to the amplified spontaneous emission light signal of the specific wavelength compensate for the lacked amplified spontaneous emission light signal of the specific wavelength. Therefore, the transmission quality is not adversely influenced by the lack of the amplified spontaneous emission light signal of the specific wavelength, and the configuration of the wavelength division multiplexing and optical transmission apparatus having a high redundancy can be obtained.

In the wavelength division multiplexing and optical transmission apparatus according to the present invention, the optical amplifying means comprises an optical amplifier which has a signal input terminal terminated at no reflection, and a plurality of pumping laser signal sources connected to the optical amplifier redundantly.

In the above configuration, the optical amplifying means comprises an optical amplifier which has a signal input terminal terminated at

no reflection, and the pumping laser signal sources connected to the optical amplifier redundantly. Therefore, even though one pumping laser signal source is put in an inoperative condition, an output of the other supplement pumping laser signal source is supplied to the optical amplifier. Accordingly, the optical amplification can be stably continued in the optical amplifier, the reliability for the optical amplifier can be heightened.

In the wavelength division multiplexing and optical transmission apparatus according to the present invention, the band pass filtering means comprises a plurality of optical band pass filters connected in cascade.

In the above configuration, the band pass filtering means comprises the optical band pass filters connected in cascade. Therefore, an attenuation form of the spectrum slice optical signal in a given wavelength band can be strictly specified, an S/N ratio of signals can be heightened, and the transmission quality can be heightened.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the configuration of an example of a conventional wavelength division multiplexing and optical transmission apparatus.

Fig. 2 is a view showing a spectral distribution of modulated optical signals and dummy optical signals transmitted in the wavelength division multiplexing.

Fig. 3 is a block diagram showing the configuration of a wavelength division multiplexing and optical transmission apparatus according to a first embodiment of the present invention.

Fig. 4 is a view showing output characteristics of an optical amplifier shown in Fig. 3.

Fig. 5 is a view showing filtering characteristics of an optical

band pass filter shown in Fig. 3.

Fig. 6 is a block diagram showing the configuration of a wavelength division multiplexing and optical transmission apparatus according to a second embodiment of the present invention.

5 Fig. 7 is a block diagram showing the configuration of a wavelength division multiplexing and optical transmission apparatus according to a third embodiment of the present invention.

Fig. 8 is a block diagram showing the configuration of an important portion of a wavelength division multiplexing and optical transmission apparatus according to a fourth embodiment of the present invention.

Fig. 9 is a block diagram showing the configuration of an important portion of a wavelength division multiplexing and optical transmission apparatus according to a fifth embodiment of the present invention.

15 BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the best mode for carrying out the present invention will now be described with reference to the accompanying drawings to explain the present invention in more detail.

EMBODIMENT 1

20 Fig. 3 is a block diagram showing the configuration of a wavelength division multiplexing and optical transmission apparatus according to a first embodiment of the present invention. In Fig. 3, 10 indicates a wavelength division multiplexing and optical transmission apparatus. 1-m to 1+m indicate a plurality of optical transmitting units for
 25 modulating each of a plurality of laser signals having wavelengths λ -m to λ +m different from each other with a data signal and outputting a plurality of modulated optical signals. The number of optical transmitting units 1-m to 1+m is 2m. 12a and 12b indicate optical amplifiers (or optical amplifying means). An input end terminal of
 30 each optical amplifier 12a or 12b is terminated at no reflection. 13a

and 13b indicate two optical band pass filters (or band pass filtering means) for respectively outputting a spectrum slice optical signal. 14 indicates an optical multiplexer (or optical multiplexing means) for multiplexing the spectrum slice optical signals with the modulated optical signals. 15 indicates an optical fiber through which an optical output signal multiplexed in the optical multiplexer 14 is transmitted. Here, in this first embodiment, the optical band pass filter 13a corresponds to a high frequency optical band pass filter in which an output of the optical amplifier 12a is filtered and a non-modulated high frequency spectrum slice optical signal, namely, a non-modulated shorter wavelength spectrum slice optical signal is output, and the optical band pass filter 13b corresponds to a low frequency optical band pass filter in which an output of the optical amplifier 12b is filtered and a non-modulated low frequency spectrum slice optical signal, namely, a non-modulated longer wavelength spectrum slice optical signal is output. However, it is applicable that each of the optical band pass filters 13a and 13b be formed of an optical band pass filter corresponding to a wavelength band (or frequency band) which is placed within a wavelength band occupied by the modulated optical signals output from the optical transmitting units 1-m to 1+m.

Next an operation will be described below.

A plurality of laser signals having wavelengths $\lambda-m$ to $\lambda+m$ different from each other are modulated by using a plurality of data signals in the optical transmitting units 1-m to 1+m, of which the number is $2m$, in one-to-one correspondence, and a plurality of modulated optical signals are output. Each of the modulated optical signals of the $2m$ wavelengths (the number $2m$ of wavelengths is normally equal to a value ranging from 4 to 16) output from the optical transmitting units 1-m to 1+m has a spectral line width. A plurality of divided wavelength bands are obtained by dividing the optical transmission wavelength

band at equal intervals in a direction from the shorter wavelength side to the longer wavelength side, and a wavelength band of each modulated optical signal having the spectral linewidth is placed within the corresponding divided wavelength band. The modulated optical signals are arranged in a form of shifting the wavelength at constant wavelength intervals from the shorter wavelength side to the longer wavelength side. Each of the optical amplifiers 12a and 12b is formed of a non-input optical amplifier in which an input end is terminated at no reflection to cut off an input signal, and a broadband amplified spontaneous emission light signal called amplified spontaneous emission light (ASE) emitted from an erbium doped fiber, in which energy of a pumping laser signal source (not shown) is absorbed, is output from each of the optical amplifiers 12a and 12b. As shown in Fig. 4, this broadband amplified spontaneous emission light signal has a spectral distribution in which the gain is almost uniformly distributed over the entire wavelength band. Also, when the amplified spontaneous emission light signal is transmitted through each of the optical band pass filters 13a and 13b, as shown in Fig. 5, components of the amplified spontaneous emission light signal having wavelengths other than a specific wavelength are filtered off in each optical band pass filter 13a or 13b, and only a component of the amplified spontaneous emission light signal having the specific wavelength is transmitted through each optical band pass filter. In detail, the amplified spontaneous emission light signals having wavelengths, which are placed on the outside and are adjacent to the wavelength band occupied by the modulated optical signals output from the optical transmitting units 1-m to 1+m, are output from the optical band pass filters 13a and 13b. That is to say, a spectrum slice optical signal of a wavelength λ_{da} and a spectrum slice optical signal of a wavelength λ_{db} are output from the optical band pass filters 13a and 13b. Here, the spectrum slice

optical signal of the wavelength λ_{da} is adjacent to the shorter wavelength side of the modulated optical signal having the wavelength $\lambda - m$, and the spectrum slice optical signal of the wavelength λ_{db} is adjacent to the longer wavelength side of the modulated optical signal having the wavelength $\lambda + m$. As is apparent from the production process of the spectrum slice optical signals, each spectrum slice optical signal is not modulated.

The spectrum slice optical signals output from the optical band pass filters 13a and 13b are multiplexed with the modulated optical signals output from the optical transmitting units 1-m to 1+m in the optical multiplexer 14 and are transmitted through the optical fiber 15. In this case, the spectrum slice optical signals placed on both sides of the wavelength band occupied by the modulated optical signals function so as to reduce a peak power of each modulated optical signal, and a gain distribution of the modulated optical signals in the optical transmission wavelength band of each optical amplifier repeater is flattened by the spectrum slice optical signals. In detail, gains of modulated optical signals placed on the shorter wavelength side among the modulated optical signals output from the optical transmitting units 1-m to 1+m are reduced by the spectrum slice optical signal of the wavelength λ_{da} output from the optical band pass filter 13a, and gains of modulated optical signals placed on the longer wavelength side among the modulated optical signals output from the optical transmitting units 1-m to 1+m are reduced by the spectrum slice optical signal of the wavelength λ_{db} output from the optical band pass filter 13b. Therefore, output powers of the modulated optical signals output from the optical transmitting units 1-m to 1+m are reduced to such a degree that the modulated optical signals do not cause non-linear optical effects, and the transmission quality of the modulated optical signals is improved. Also, the spectrum slice optical signals of the

wavelengths λ_{da} and λ_{db} placed on both sides of the wavelength band occupied by the modulated optical signals compensate the gain differences caused in the optical amplifier repeaters. Therefore, an output power distribution of the modulated optical signals output from the optical transmitting units 1-m to 1+m is flattened in the transmission wavelength band of each optical amplifier repeater, and the transmission quality of the modulated optical signals is improved.

As is described above, in the first embodiment, the amplified spontaneous emission light signals are output by using the non-input optical amplifiers 12a and 12b, the amplified spontaneous emission light signals are filtered in the optical band pass filters 13a and 13b to obtain the spectrum slice optical signals, and the spectrum slice optical signals functioning as dummy optical signals are multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signals or band components of the spectrum slice optical signals can be arbitrarily processed. Also, because the spectrum slice optical signals differ from the conventional dummy optical signals which each are emitted from a laser diode functioning as a dummy optical signal source and have a single wavelength, there is no probability that the stimulated Brillouin scattering denoting one fiber non-linear phenomenon is caused due to a narrow spectral line width of the output optical signal so as to degrade the transmission quality, and there is no probability that a polarization scrambler is required to prevent the deterioration of an S/N ratio caused by the polarization dependent gain (PDG) of each optical amplifier repeater placed on the way along the transmission line. Accordingly, the enlarging of the size of the wavelength division multiplexing and optical transmission apparatus can be suppressed, and the cost of the production of the wavelength division multiplexing and optical transmission apparatus can be reduced. Also, in cases where

a technical improvement is performed to widen the wavelength band occupied by the modulated optical signals for the purpose of increasing the number $2m$ of wavelengths of the modulated optical signals, the technical improvement can be performed by only changing the optical band pass filters 13a and 13b connected to the optical amplifiers 12a and 12b to those having required band pass filtering characteristics. Therefore, it is not required to newly prepare a dummy optical signal source possible to be accommodated to a new system, and the new system of the wavelength division multiplexing and optical transmission apparatus can be obtained without increasing the cost.

EMBODIMENT 2

Fig. 6 is a block diagram showing the configuration of a wavelength division multiplexing and optical transmission apparatus according to a second embodiment of the present invention. In Fig. 6, 20 indicates a wavelength division multiplexing and optical transmission apparatus. $2-m$ to $2+m$ indicate a plurality of optical transmitting units for modulating a plurality of laser signals having wavelengths $\lambda-m$ to $\lambda+m$ different from each other with a data signal and outputting a plurality of modulated optical signals. 22 indicates an optical amplifier (or optical amplifying means). An input end of the optical amplifier 22 is terminated at no reflection to cut off an input signal. 23 indicates a light dividing element connected to an output end terminal of the optical amplifier 22. 23_1 to 23_n indicate a plurality of optical band pass filters connected to a plurality of divided output terminals of the light dividing element 23 respectively. The number of divided output terminals of the light dividing element 23 is n . 24 indicates an optical multiplexer for multiplexing a plurality of spectrum slice optical signals output from the optical band pass filters 23_1 to 23_n with the modulated optical signals output from the optical transmitting

units $2-m$ to $2+m$. 25 indicates an optical fiber through which an optical output signal multiplexed in the optical multiplexer 24 is transmitted. Here, in this second embodiment, a band pass filtering means comprises the light dividing element 23 and the optical band pass filters 23_1 to 23_n (of which the number is n).

Next an operation will be described below.

A plurality of laser signals having wavelengths $\lambda-m$ to $\lambda+m$ different from each other are modulated by using a plurality of data signals in the optical transmitting units $2-m$ to $2+m$, of which the number is $2m$, in one-to-one correspondence, and a plurality of modulated optical signals are output. Each of the modulated optical signals of the $2m$ wavelengths (the number $2m$ of wavelengths is normally equal to a value ranging from 4 to 16) output from the optical transmitting units $2-m$ to $2+m$ has a spectral line width. A plurality of divided wavelength bands are obtained by dividing an optical transmission wavelength band at equal intervals in a direction from the shorter wavelength side to the longer wavelength side, and a wavelength band of each modulated optical signal having the spectral line width is placed within one corresponding divided wavelength band. The modulated optical signals are arranged in a form of shifting the wavelength at constant wavelength intervals from the shorter wavelength side to the longer wavelength side. Because the optical amplifier 22 is formed of a non-input optical amplifier in which an input signal is cut off, and a broadband amplified spontaneous emission light signal called the amplified spontaneous emission light (ASE) described before is output from the optical amplifier 22. The amplified spontaneous emission light signal is divided into a plurality of laser signals (of which the number is n) in the light dividing element 23. Also, when the branched laser signals are transmitted through the optical band pass filters 23_1 to 23_n respectively, components of each divided laser signal having wavelengths other than

a specific wavelength are filtered off in the corresponding optical band pass filter, and a plurality of spectrum slice optical signals of specific wavelengths λ_{d1} to λ_{d2} are transmitted through the optical band pass filters 23_1 to 23_n respectively. In detail, in cases where

5 integral numbers i and j are set to arbitral numbers adjacent to each other in a series of integral numbers 1 to n , a plurality of spectrum slice optical signals of specific wavelengths λ_{d1} to λ_{di} adjacent to the shorter wavelength side of the wavelength band occupied by the modulated optical signals are output from the optical band pass filters

10 23_1 to 23_i respectively, and a plurality of spectrum slice optical signals of specific wavelengths λ_{dj} to λ_{dn} adjacent to the longer wavelength side of the wavelength band occupied by the modulated optical signals are output from the optical band pass filters 23_j to 23_n respectively. In this case, it is applicable that each of the optical

15 band pass filters 23_1 to 23_n be formed of an optical band pass filter corresponding to a wavelength band which is placed within a wavelength band occupied by the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$.

The spectrum slice optical signals output from the optical band pass

20 filters 23_1 to 23_n are multiplexed with the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$ in the optical multiplexer 24 and are transmitted through the optical fiber 25. In this case, the spectrum slice optical signals placed on both sides of the wavelength band occupied by the modulated optical signals

25 function so as to reduce a peak power of each modulated optical signal. In detail, gains of modulated optical signals placed on the shorter wavelength side among the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$ are reduced by the spectrum slice optical signals of the wavelengths λ_{d1} to λ_{di} output from the optical

30 band pass filters 23_1 to 23_i (of which the number is i), and gains

of modulated optical signals placed on the longer wavelength side among the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$ are reduced by the spectrum slice optical signals of the wavelengths λ_{dj} to λ_{dn} output from the optical bandpass filters 23j to 23n (of which the number is $n-i$).

Therefore, output powers of the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$ are reduced to such a degree that the modulated optical signals do not cause non-linear optical effects in the transmission wavelength band of each optical amplifier repeater, and the transmission quality of the modulated optical signals is improved. Also, the spectrum slice optical signals of the wavelengths λ_{d1} to λ_{dn} placed on both sides of the wavelength band occupied by the modulated optical signals compensate the gain differences of the optical amplifier repeaters. In detail, the spectrum slice optical signals (of which the number is i) of the wavelengths λ_{d1} to λ_{di} output from the optical band pass filters 23₁ to 23_i are multiplexed as a plurality of dummy optical signals with the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$, and a multiplexed optical signal is input to each optical amplifier repeater. Because the number of wavelengths of the multiplexed optical signal input to the optical amplifier repeater approaches the designed number of wavelengths, the same gain profile as that of the optical amplifier repeater can be maintained in the optical amplifier repeater, a gain distribution of the modulated optical signals output from the optical transmitting units $2-m$ to $2+m$ is flattened in the optical amplifier repeater, and the transmission quality of the modulated optical signals can be improved.

As is described above, in the second embodiment, the amplified spontaneous emission light signal is output by using the non-input optical amplifier 22, the divided laser signals (of which the number

is n) obtained by dividing the amplified spontaneous emission light signal are filtered in the optical band pass filters 23_1 to 23_n respectively to produce the spectrum slice optical signals, and the spectrum slice optical signals functioning as dummy optical signals are multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signals or band components of the spectrum slice optical signals can be arbitrarily processed by using the band pass filtering means of a minimum size which is obtained by combining the single optical amplifier 22 and the optical bandpass filters 23_1 to 23_n . Therefore, because the spectrum slice optical signals differ from the conventional dummy optical signals which each are emitted from a laser diode functioning as a laser signal source and have a single wavelength, there is no probability that the stimulated Brillouin scattering denoting one fiber non-linear phenomenon is caused due to a narrow spectral line width of the output laser signal to degrade the transmission quality, and there is no probability that a polarization scrambler is required to prevent the deterioration of an S/N ratio caused by the polarization dependent gain (PDG) of each optical amplifier repeater placed on the way along the transmission line. Accordingly, the enlarging of the size of the wavelength division multiplexing and optical transmission apparatus can be suppressed, and the cost of the production of the wavelength division multiplexing and optical transmission apparatus can be reduced. Also, in cases where a technical improvement is performed to widen the wavelength band occupied by the modulated optical signals for the purpose of increasing the number $2m$ of wavelengths of the modulated optical signals, the technical improvement can be performed by only changing the optical band pass filters 23_1 to 23_m connected to the single optical amplifier 22 through the light dividing element 23 to those having required band pass filtering characteristics. Therefore,

it is not required to newly prepare a dummy optical signal source possible to be accommodated to a new system, and the new system of the wavelength division multiplexing and optical transmission apparatus can be obtained without increasing the cost.

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EMBODIMENT 3

Fig. 7 is a block diagram showing the configuration of a wavelength division multiplexing and optical transmission apparatus according to a third embodiment of the present invention. In Fig. 7, 30 indicates a wavelength division multiplexing and optical transmission apparatus. 3-m to 3+m indicate a plurality of optical transmitting units for modulating a plurality of laser signals having wavelengths λ -m to λ +m different from each other with a data signal and outputting a plurality of modulated optical signals. 32 indicates an optical amplifier. An input end of the optical amplifier 32 is terminated at no reflection to cut off an input signal. 33 indicates a light dividing element connected to an output end terminal of the optical amplifier 32. 33₁ to 33_n indicate a plurality of optical bandpass filters connected to a plurality of divided output terminals of the light dividing element 33 respectively. The number of divided output terminals of the light dividing element 33 is n. Output signals of the optical bandpass filters 33₁ to 33_n are classified into k blocks. 36₁ to 36_k indicate a plurality of optical multiplexers for respectively multiplexing the output signals of the optical band pass filters of the corresponding block with each other. 37₁ to 37_k indicate a plurality of optical amplifiers connected to a plurality of output terminals of the optical multiplexers 36₁ to 36_k respectively. 38 indicates an optical multiplexer for multiplexing the output signals of the optical band pass filters 33₁ to 33_n with each other. 34 indicates an optical multiplexer for multiplexing a plurality of spectrum slice optical signals output from

30

the optical multiplexer 38 with the modulated optical signals output from the optical transmitting units 3-m to 3+m. 35 indicates an optical fiber through which an optical output signal multiplexed in the optical multiplexer 34 is transmitted. Here, in this third embodiment, a band pass filtering means comprises the light dividing element 33, the optical band pass filters 33₁ to 33_n, the optical multiplexers 36₁ to 36_k, the optical amplifiers 37₁ to 37_k and the optical multiplexer 38. However, the optical multiplexer 38 can be omitted. In this case, output signals of the optical amplifiers 37₁ to 37_k are directly input to the optical multiplexer 34.

Next an operation will be described below.

A plurality of laser signals having wavelengths λ -m to λ +m different from each other is modulated by using a plurality of data signals in the optical transmitting units 3-m to 3+m, of which the number is 2m, in one-to-one correspondence, and a plurality of modulated optical signals are output. Each of the modulated optical signals of the 2m wavelengths (the number 2m of wavelengths is normally equal to a value ranging from 4 to 16) output from the optical transmitting units 3-m to 3+m has a spectral line width. A plurality of divided wavelength bands are obtained by dividing an optical transmission wavelength band at equal intervals in a direction from the shorter wavelength side to the longer wavelength side, and a wavelength band of each modulated optical signal having the spectral line width is placed within one corresponding divided wavelength band. The modulated optical signals are arranged in a form of shifting the wavelength at constant wavelength intervals from the shorter wavelength side to the longer wavelength side. Because the optical amplifier 32 is formed of a non-input optical amplifier, and a broadband amplified spontaneous emission light signal called the amplified spontaneous emission light (ASE) described before is output from the optical amplifier 32. The amplified spontaneous

emission light signal output from the optical amplifier 32 is divided into a plurality of amplified spontaneous emission light signals (of which the number is n) in the light dividing element 33 of a next stage. Thereafter, the amplified spontaneous emission light signals are lead

5 to the optical bandpass filters 33₁ to 33_n respectively. In the optical bandpass filters 33₁ to 33_n, components of each amplified spontaneous emission light signal having wavelengths other than a specific wavelength are filtered off, and the amplified spontaneous emission light signals having specific wavelengths λ_{d1} to λ_{dn} respectively

10 are obtained. The filtered amplified spontaneous emission light signals (of which the number is n) are classified into k blocks, and each block of filtered amplified spontaneous emission light signals is supplied to the corresponding one of the optical multiplexers 36₁ to 36_k. Here, the symbol k denotes an arbitrary number included in the integral numbers

15 from 1 to n . The blocks of the amplified spontaneous emission light signals multiplexed in the optical multiplexers 36₁ to 36_k are amplified in the optical amplifiers 37₁ to 37_k respectively and are multiplexed with each other in the optical multiplexer 38. The amplified spontaneous emission light signals multiplexed with each other in the optical

20 multiplexer 38 function as a plurality of spectrum slice optical signals having wavelengths λ_{d1} to λ_{dn} adjacent to both sides of a wavelength band occupied by the multiplexed optical signals output from the optical transmitting units 3-m to 3+m.

The first half blocks of spectrum slice optical signals among the

25 k blocks of the spectrum slice optical signals of the wavelengths λ_{d1} to λ_{dn} multiplexed with each other in the optical multiplexer 38 correspond to a group of wavelengths following the wavelength band occupied by the multiplexed optical signals on the shorter wavelength side, and the latter half blocks of spectrum slice optical signals

30 among the k blocks of the spectrum slice optical signals correspond

to a group of wavelengths following the wavelength band occupied by the multiplexed optical signals on the longer wavelength side. The spectrum slice optical signals output from the optical multiplexer 38 are multiplexed with the multiplexed optical signals output from the optical transmitting units 3-m to 3+m in the optical multiplexer 34, and a multiplexed optical signal is transmitted through the optical fiber 35. In this case, the spectrum slice optical signals placed on both sides of the wavelength band occupied by the modulated optical signals function so as to reduce a peak power of each modulated optical signal. In detail, gains of modulated optical signals placed on the shorter wavelength side among the modulated optical signals output from the optical transmitting units 3-m to 3+m are reduced by the first blocks of spectrum slice optical signals selected among the k blocks of the spectrum slice optical signals, and gains of modulated optical signals placed on the longer wavelength side among the modulated optical signals output from the optical transmitting units 3-m to 3+m are reduced by the latter blocks of spectrum slice optical signals selected among the k blocks of the spectrum slice optical signals. Therefore, output powers of the modulated optical signals output from the optical transmitting units 3-m to 3+m are reduced to such a degree that the modulated optical signals do not cause non-linear optical effects in the transmission wavelength band of each optical amplifier repeater, and the transmission quality of the modulated optical signals is improved.

Also, the spectrum slice optical signals of the wavelengths λ_{d1} to λ_{dn} compensate the gain differences of the optical amplifier repeaters. In detail, the spectrum slice optical signals (of which the number is i) of the wavelengths λ_{d1} to λ_{di} output from the optical band pass filters 33₁ to 33_i are multiplexed as a plurality of dummy optical signals with the modulated optical signals output from the optical

transmitting units $3-m$ to $3+m$, and the multiplexed optical signal is input to each optical amplifier repeater. Because the number of wavelengths of the multiplexed optical signal input to the optical amplifier repeater approaches the designed number of wavelengths, the same gain profile as that of the optical amplifier repeater can be maintained in the optical amplifier repeater, a gain distribution of the modulated optical signals output from the optical transmitting units $3-m$ to $3+m$ is flattened in the optical amplifier repeater, and the transmission quality of the modulated optical signals can be improved.

Also, assuming that one of spectrum slice optical signal sources is put in an inoperative condition and no amplified spontaneous emission light signal of a wavelength λ_g is output from an optical amplifier 37h (h denotes an integral number ranging from 1 to k) installed for a laser signal of the wavelength λ_g , a plurality of amplified spontaneous emission light signals belonging to the same block as that of the lacked amplified spontaneous emission light signal of the wavelength λ_g are input to the optical amplifier 37h and are amplified at gains stronger than those in a case of no lack of the amplified spontaneous emission light signal of the wavelength λ_g . As a result, the gain emphasized amplified spontaneous emission light signals of wavelengths adjacent to the wavelength λ_g compensate for the lack of the amplified spontaneous emission light signal of the wavelength λ_g , and the transmission quality is not substantially adversely influenced by the lack of the amplified spontaneous emission light signal of the wavelength λ_g . In other words, the wavelength division multiplexing and optical transmission apparatus 30 can have the device configuration having a high redundancy to the lack of a specific wavelength.

As is described above, in the third embodiment, the broadband amplified spontaneous emission light signal is output by using the single optical

amplifier 32 of which the input terminal is terminated at no reflection, the divided amplified spontaneous emission light signals (of which the number is n) obtained by dividing the amplified spontaneous emission light signal are filtered in the optical band pass filters 33_1 to 33_n respectively to produce the spectrum slice optical signals, and the spectrum slice optical signals functioning as dummy optical signals are multiplexed with the modulated optical signals. Therefore, a wavelength band occupied by the spectrum slice optical signals or band components of the spectrum slice optical signals can be arbitrarily processed. Therefore, because the spectrum slice optical signals differ from the conventional dummy optical signals which each are emitted from a laser diode functioning as a dummy optical signal source and have a single wavelength, there is no probability that the stimulated Brillouin scattering denoting one fiber non-linear phenomenon is caused due to a narrow spectral line width of the output laser signal to degrade the transmission quality, and there is no probability that a polarization scrambler is required to prevent the deterioration of an S/N ratio caused by the polarization dependent gain (PDG) of each optical amplifier repeater placed on the way along the transmission line. Accordingly, the enlarging of the size of the wavelength division multiplexing and optical transmission apparatus can be suppressed, and the cost of the production of the wavelength division multiplexing and optical transmission apparatus can be reduced. Also, in cases where a technical improvement is performed to widen the wavelength band occupied by the modulated optical signals for the purpose of increasing the number $2m$ of wavelengths of the modulated optical signals, the technical improvement can be performed by only changing the optical band pass filters 33_1 to 33_m connected to the single optical amplifier 32 through the light dividing element 33 to those having required band pass filtering characteristics. Therefore, it is not required to newly

prepare a dummy optical signal source possible to be accommodated to a new system, and the new system of the wavelength division multiplexing and optical transmission apparatus can be obtained without increasing the cost. Also, even though one of spectrum slice optical signal sources is put in an inoperative condition so as to lack an amplified spontaneous emission light signal of a specific wavelength, the redundancy is exerted in one of the optical amplifiers 37₁ to 37_k so as to emphasize gains of amplified spontaneous emission light signals of wavelengths adjacent to the specific wavelength of the lacked amplified spontaneous emission light signal. Therefore, the transmission quality is not adversely influenced by the lack of the amplified spontaneous emission light signal of the specific wavelength.

EMBODIMENT 4

Fig. 8 is a block diagram showing the configuration of an important portion of a wavelength division multiplexing and optical transmission apparatus according to a fourth embodiment of the present invention. In Fig. 8, 41 indicates a pumping laser signal source device called a pump laser diode. 41a and 41b indicate a pair of laser diodes (or pumping laser signal sources) installed in the pumping laser signal source device 41 so as to give redundancy to the laser diodes 41a and 41b. 42 indicates an optical amplifier (or optical amplifying means).

Next an operation will be described below.

In a normal operation, one of the laser diodes 41a and 41b installed in the pumping laser signal source device 41, for example, only the laser diode 41a is operated, and an excitation laser signal is supplied to the optical amplifier 42. However, when the laser diode 41a normally used is broken down and is put in an inoperative condition, the other laser diode 41b installed as a supplemental one is operated in place of the laser diode 41a. Therefore, even though the laser diode 41a

is put in an inoperative condition, no adverse influence is exerted on the wavelength division multiplexing and optical transmission apparatus.

As is described above, in the fourth embodiment, even though the laser diode 41a is put in an inoperative condition, an excitation laser signal emitted from the supplemental laser diode 41b can be supplied to the optical amplifier 42. Therefore, the optical amplification can be stably continued in the optical amplifier 42, and the reliability for the optical amplifier 42 can be heightened. Here, the configuration of the optical amplifier 42 and the pumping laser signal source device 41 can be applied in place of each of the optical amplifiers 12a, 12b, 22 and 32 described in the first to third embodiments.

EMBODIMENT 5

Fig. 9 is a block diagram showing the configuration of an important portion of a wavelength division multiplexing and optical transmission apparatus according to a fifth embodiment of the present invention. In Fig. 9, 52 indicates an optical amplifier (or optical amplifying means). 53a and 53b indicate two optical band pass filters (or band pass filtering means) connected in cascade to an output terminal of the optical amplifier 52.

Next an operation will be described below.

An amplified spontaneous emission light signal output from the optical amplifier 52 is filtered in each of the optical band pass filters 53a and 53b connected in cascade. Components of unnecessary wavelength bands included in the amplified spontaneous emission light signal, which is filtered in the optical band pass filter 53a of the first stage according to filtering characteristics of the optical band pass filters 53a, are removed in the optical band pass filter 53b of the latter stage with high precision, and a desired spectrum slice optical

signal is obtained. Normally, because an attenuation form of the spectrum slice optical signal in a given wavelength band is specified, a prescribed attenuation form is strictly obtained in the spectrum slice optical signal by using the pair of optical band pass filters 5 53a and 53b connected in cascade, an S/N ratio of the spectrum slice optical signal can be improved.

As is described above, in the fifth embodiment, an attenuation form of the spectrum slice optical signal in a given wavelength band can be strictly specified, an isolation ratio of signals can be heightened, 10 and the transmission quality can be heightened. Here, a technique of the configuration of the band pass filtering means comprising a plurality of optical band pass filters can be applied in each of the first to third embodiments.

As is described above, the wavelength division multiplexing and optical transmission apparatus according to the present invention is appropriate for a large capacity of wavelength division multiplexing and optical transmission system in which a plurality of modulated optical signals can be transmitted without degrading a transmission quality of the modulated optical signals even though the number of wavelengths of the modulated optical signals installed in the early stage by using a non-input optical amplifier is small.

5

WHAT IS CLAIMED IS:

1. A wavelength division multiplexing and optical transmission apparatus comprising:

a plurality of optical transmitting units for modulating a plurality of laser signals having inherent wavelengths with a plurality of data signals and outputting a plurality of modulated optical signals;

optical amplifying means for outputting an amplified spontaneous emission light signal;

band pass filtering means for setting both an occupied wavelength band of the modulated optical signals output by the optical transmitting units and a neighboring wavelength band of the occupied wavelength band as a filtering wavelength band and band-filtering the amplified spontaneous emission light signal output by the optical amplifying means and outputting a non-modulated spectrum slice optical signal;

and

optical multiplexing means for multiplexing the non-modulated spectrum slice optical signal output by the band pass filtering means with the modulated optical signals output by the optical transmitting units and transmitting a multiplexed optical signal.

2. A wavelength division multiplexing and optical transmission apparatus according to claim 1, wherein the optical amplifying means comprises a pair of optical amplifiers which each have a signal input terminal terminated at no reflection, and the band pass filtering means comprises optical band pass filters for setting both the occupied wavelength band of the modulated optical signals output by the optical transmitting units and the neighboring wavelength band of the occupied wavelength band as the filtering wavelength band, filtering amplified spontaneous emission light signals output by the optical amplifiers and outputting non-modulated spectrum slice optical signals.

3. A wavelength division multiplexing and optical transmission apparatus according to claim 1, wherein the optical amplifying means comprises a single optical amplifier which has a signal input terminal terminated at no reflection, and the bandpass filtering means comprises
5 a light dividing element for dividing the amplified spontaneous emission light signal output by the optical amplifier into a plurality of amplified spontaneous emission light signals, and
a plurality of optical band pass filters, connected to a plurality
10 of divided output terminals of the light dividing element respectively, for outputting the non-modulated spectrum slice optical signal.

4. A wavelength division multiplexing and optical transmission apparatus according to claim 1, wherein the optical amplifying means
15 comprises a single optical amplifier which has a signal input terminal terminated at no reflection, and the bandpass filtering means comprises
a light dividing element for dividing the amplified spontaneous emission light signal output by the optical amplifier into a plurality of amplified spontaneous emission light signals,
20 a plurality of optical band pass filters connected to a plurality of divided output terminals of the light dividing element respectively,
an optical multiplexer for multiplexing two or more outputs of the optical band pass filters with each other and outputting the non-modulated spectrum slice optical signal, and
25 an optical amplifier for amplifying an output of the optical multiplexer while controlling a power of the output to a constant value.

5. A wavelength division multiplexing and optical transmission apparatus according to claim 1, wherein the optical amplifying means
30 comprises

a plurality of pumping laser signal sources connected to the optical amplifier redundantly.

6. A wavelength division multiplexing and optical transmission apparatus according to claim 1, wherein the band pass filtering means comprises a plurality of optical bandpass filters connected in cascade.

A plurality of amplified spontaneous emission light signals are output by using a plurality of optical amplifiers 12a and 12b which has a signal input terminal terminated at no reflection, the amplified spontaneous emission light signals are band-filtered in a plurality of optical band pass filters 13a and 13b respectively to obtain a plurality of spectrum slice optical signals, and the spectrum slice optical signals functioning as a plurality of dummy optical signals are multiplexed with a plurality of modulated optical signals.

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FIG. 1

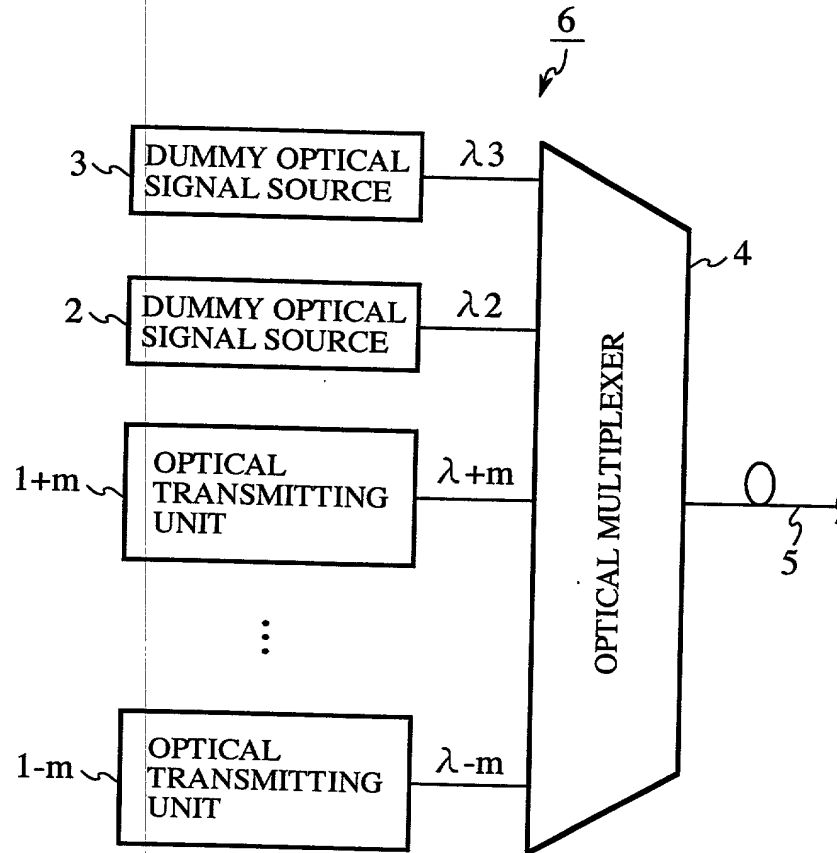


FIG. 2

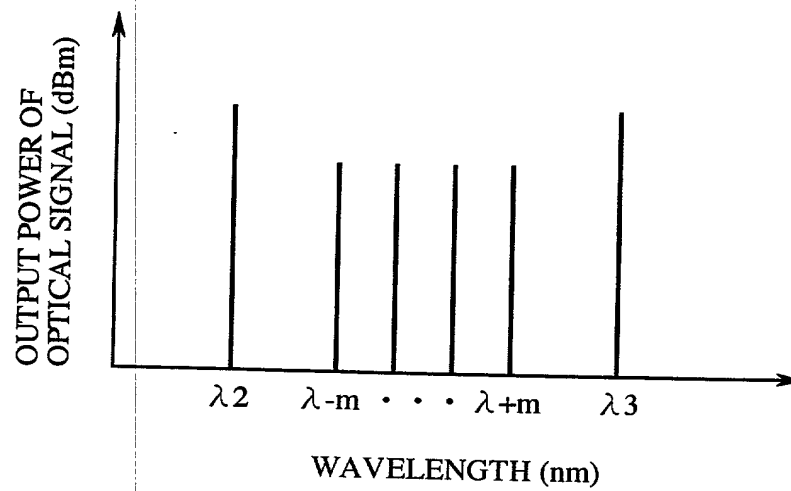
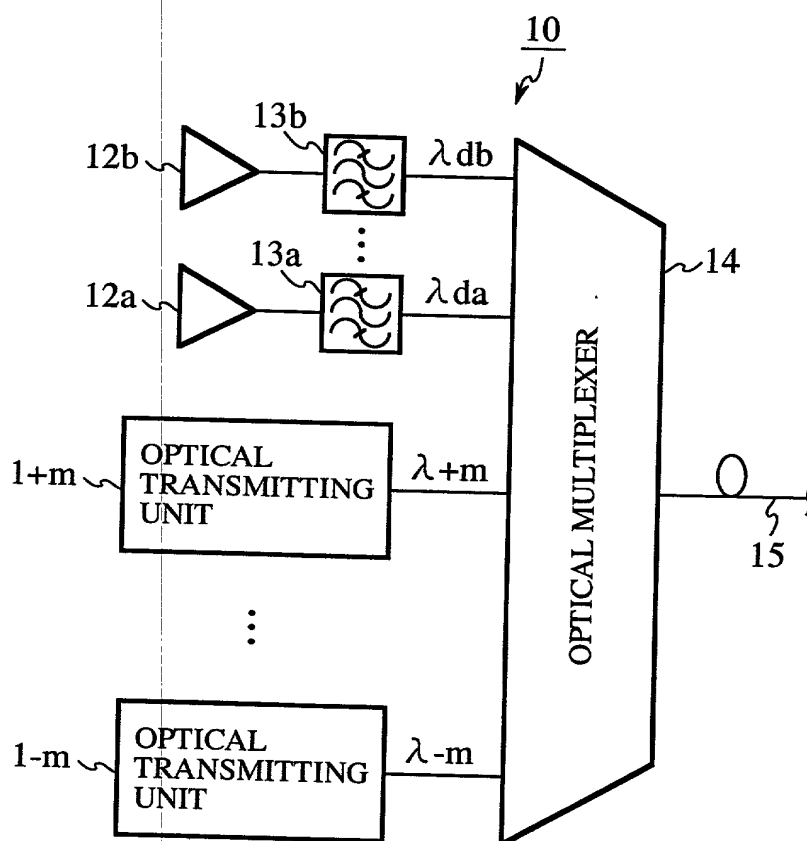


FIG.3



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FIG.4

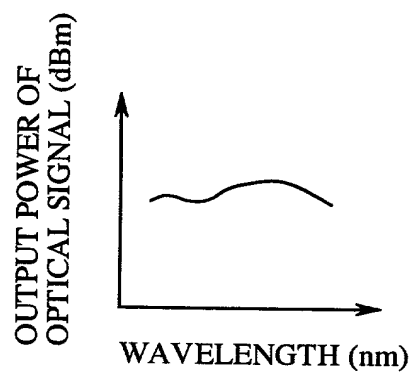


FIG.5

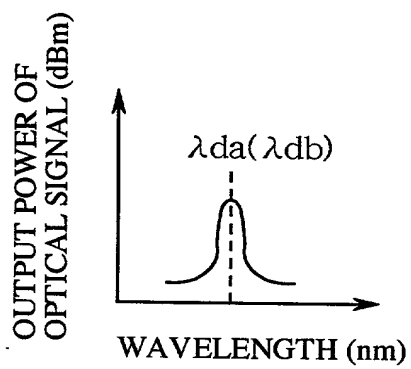
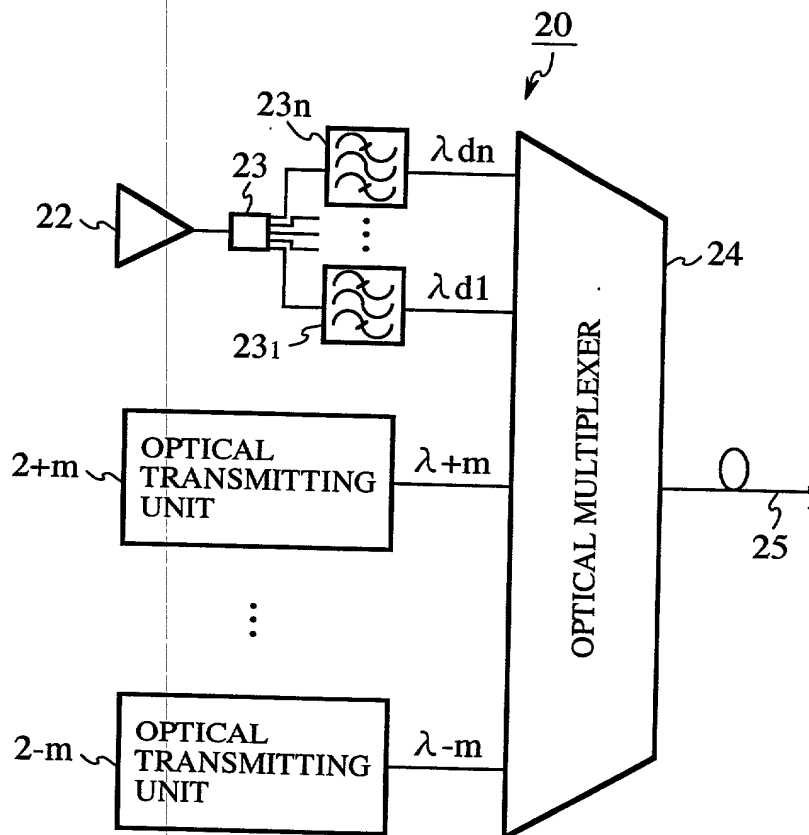
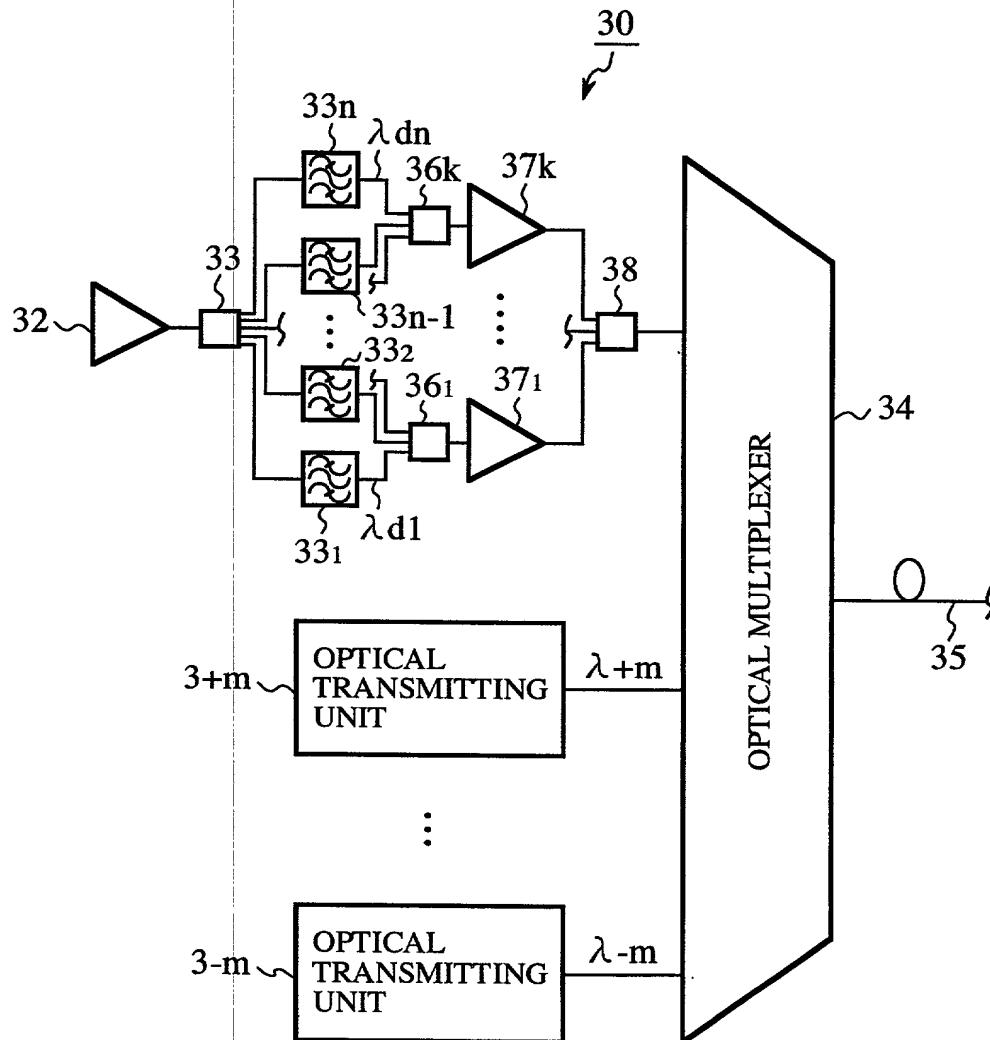


FIG.6



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FIG. 7



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FIG.8

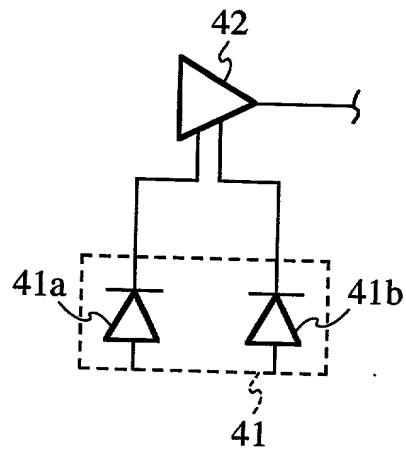
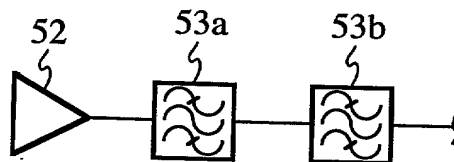


FIG.9



Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者（下記の名称が複数の場合）であると信じています。

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

"WAVELENGTH DIVISION MULTIPLEXING AND

OPTICAL TRANSMISSION APPARATUS"

the specification of which

☐ is attached hereto.

☒ was filed on 31/July/2000

as United States Application Number or

PCT International Application Number

PCT/JP00/05153 and was amended on

_____ (if applicable).

上記発明の明細書は、

☐ 本書に添付されています。

☐ ____月____日に提出され、米国出願番号または特許協定条約国際出願番号を_____とし、

(該当する場合) _____に訂正されました。

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第35編119条 (a) - (d) 項又は365条 (b) 項に基づき下記の、米国以外の国の少なくとも一カ国を指定している特許協力条約365 (a) 項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)
(Number) (番号)	(Country) (国名)

私は、第35編米国法典119条 (e) 項に基づいて下記の米国特許出願規定に記載された権利をここに主張いたします。

(Application No.) (出願番号)	(Filing Date) (出願日)
(Application No.) (出願番号)	(Filing Date) (出願日)

私は、下記の米国法典第35編120条に基づいて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約365条 (c) に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

(Application No.) (出願番号)	(Filing Date) (出願日)
(Application No.) (出願番号)	(Filing Date) (出願日)

(Application No.) (出願番号)	(Filing Date) (出願日)
(Application No.) (出願番号)	(Filing Date) (出願日)

私は、私自信の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じているところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Priority Claimed
優先権主張

<input type="checkbox"/> Yes はい	<input type="checkbox"/> No いいえ
<input type="checkbox"/> Yes はい	<input type="checkbox"/> No いいえ

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)
(Application No.) (出願番号)	(Filing Date) (出願日)

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)
(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)
(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration
(日本語宣言書)

委任状：私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。
(弁護士、または代理人の指名及び登録番号を明記のこと)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: (list name and registration number)



022850

書類送付先

Send Correspondence to:



022850

直接電話連絡先：(名前及び電話番号)

Direct Telephone Calls to: (name and telephone number)
(703) 413-3000

単独発明者または第一の共同発明者の氏名	1-00	Full name of sole or first joint inventor <u>Hiroaki MUNEHIRA</u>
発明者の署名	日付	Inventor's signature <u>Hiroaki Munehira</u> Date Feb. 19, 2002
住所		Residence <u>Tokyo, Japan JPX</u>
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o MITSUBISHI DENKI KABUSHIKI KAISHA, 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8310 Japan
第二の共同発明者の氏名	2-00	Full name of second joint inventor, if any <u>Takashi MIZUOCHI</u>
第二の共同発明者の署名	日付	Second joint Inventor's signature <u>Takashi Mizuochi</u> Date Feb. 19, 2002
住所		Residence <u>Tokyo, Japan JPX</u>
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o MITSUBISHI DENKI KABUSHIKI KAISHA, 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8310 Japan

(第三以降の共同発明者についても同様に記載し、署名すること)

(Supply similar information and signature for third and subsequent joint inventors.)

Japanese Language Declaration

(日本語宣言書)

第三の共同発明者の氏名	3-00	Full name of third joint inventor, if any <u>Nobuyuki TAKEMURA</u>
第三の共同発明者の署名	日付	Third joint Inventor's signature <u>Nobuyuki Takemura</u> Date Feb. 19, 2002
住所		Residence <u>Tokyo, Japan JPX</u>
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o MITSUBISHI DENKI KABUSHIKI KAISHA, 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8310 Japan

第四の共同発明者の氏名	4-00	Full name of fourth joint inventor, if any <u>Katsuhiko SHIMIZU</u>
第四の共同発明者の署名	日付	Fourth joint Inventor's signature <u>Katsuhiko Shimizu</u> Date Feb. 19, 2002
住所		Residence <u>Tokyo, Japan JPX</u>
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o MITSUBISHI DENKI KABUSHIKI KAISHA, 2-3, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8310 Japan

第五の共同発明者の氏名	5-00	Full name of fifth joint inventor, if any <u>Eiichi SHIBANO</u>
第五の共同発明者の署名	日付	Fifth joint Inventor's signature <u>Eiichi Shibano</u> Date Feb. 19, 2002
住所		Residence <u>Tokyo, Japan JPX</u>
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o KDDI SUBMARINE CABLE SYSTEMS INC., 7-1, Nishi-shinjuku 3-chome, Shinjuku-ku, Tokyo 163-1033 Japan

第六の共同発明者の氏名	6-00	Full name of sixth joint inventor, if any <u>Tadami YASUDA</u>
第六の共同発明者の署名	日付	Sixth joint Inventor's signature <u>Tadami Yasuda</u> Date Feb. 19, 2002
住所		Residence <u>Tokyo, Japan JPX</u>
国籍		Citizenship Japanese
郵便の宛先		Post Office Address c/o KDDI SUBMARINE CABLE SYSTEMS INC., 7-1, Nishi-shinjuku 3-chome, Shinjuku-ku, Tokyo 163-1033 Japan

(第六またはそれ以降の共同発明者に対しても同様な情報および署名を提供すること。)

(Supply similar information and signature for third and subsequent joint inventors.)

第七の共同発明者の氏名 (該当する場合)		7-00	Full name of seventh joint inventor, if any
同第七発明者の署名	日付	Atsuko OKAYASU	Seventh inventor's signature Date
住所		Atsuko Okayasu	Feb. 19, 2002
国籍		Tokyo, Japan JPK	Residence
郵便の宛先		Japanese	Citizenship
		c/o KDDI SUBMARINE CABLE SYSTEMS INC.,	Post office address
		7-1, Nishi-shinjuku 3-chome, Shinjuku-ku,	
		Tokyo 163-1033 Japan	
第八の共同発明者の氏名 (該当する場合)			Full name of eighth joint inventor, if any
同第八発明者の署名	日付		Eighth inventor's signature Date
住所			Residence
国籍			Citizenship
郵便の宛先			Post office address
第九の共同発明者の氏名 (該当する場合)			Full name of ninth inventor, if any
同第九発明者の署名	日付		Ninth inventor's signature Date
住所			Residence
国籍			Citizenship
郵便の宛先			Post office address
第十の共同発明者の氏名 (該当する場合)			Full name of tenth joint inventor, if any
同第十発明者の署名	日付		Tenth inventor's signature Date
住所			Residence
国籍			Citizenship
郵便の宛先			Post office address